ACIX

Atmospheric Correction Inter-comparison eXercise

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- What?

- International collaborative initiative to **inter-compare** a set of **atmospheric correction (AC) processors** for high-spatial resolution optical sensors
- Focus on **Landsat-8** and **Sentinel-2** imagery

- Better understanding of the different uncertainty contributors and help in improving the AC processors

- Why?

- **Free** and **open** access policy to **Landsat-8** and **Sentinel-2** imagery has stimulated the development and operational use of AC processors for generating Bottom-of-Atmosphere (BOA) products

- ACIX results are expected to point out:
  - **strengths & weaknesses**
  - **commonalities & differences**

  of **AC processors** for their further improvement

- How?

ACIX will be performed in **three** phases:

1. **Definition of the inter-comparison protocol:**

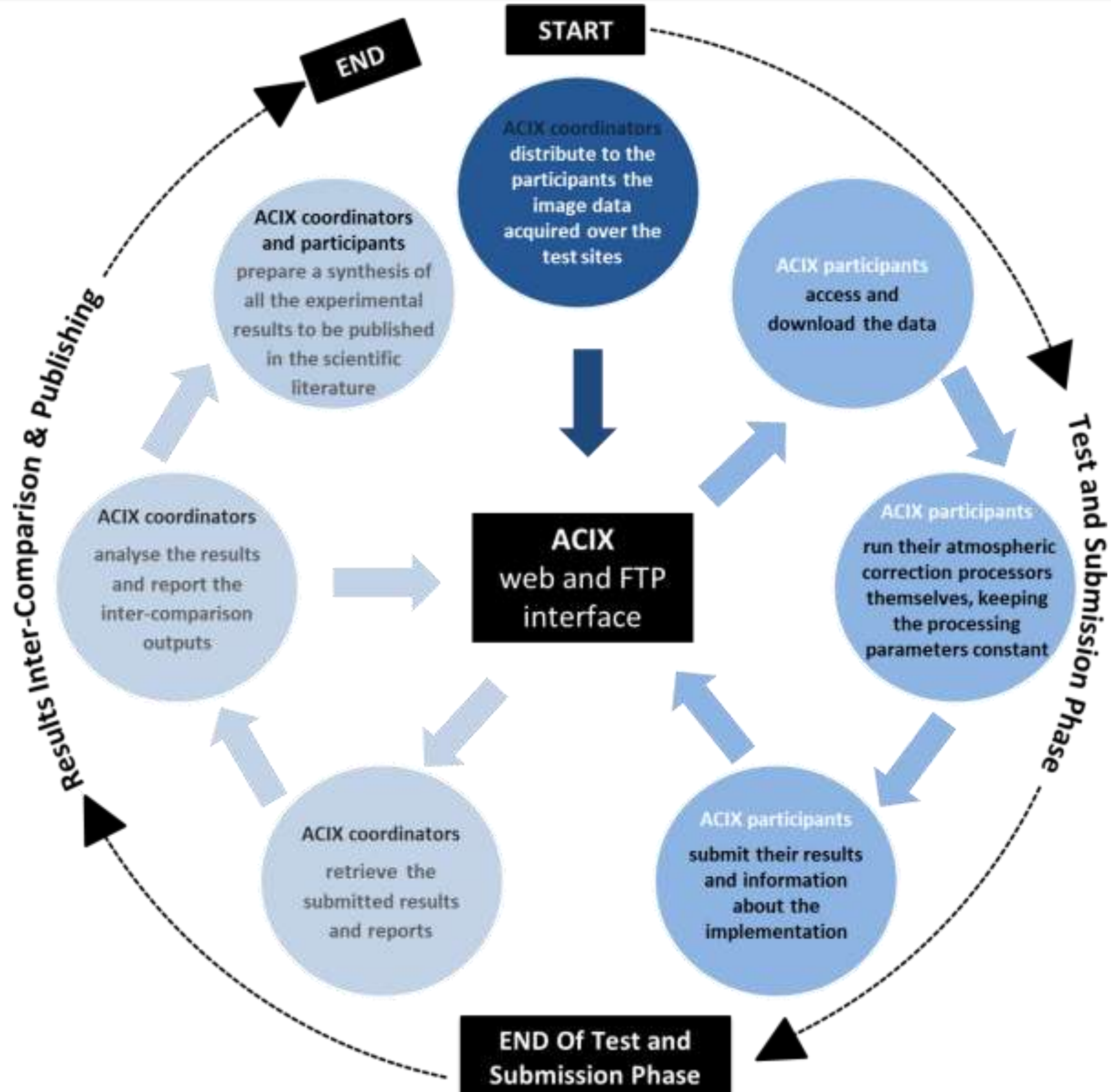
   Participants are invited to provide their feedback on the suggested protocol for the AC processors inter-comparison. All the proposals will be discussed at the 1st workshop and the final inter-comparison procedure will be agreed by all participants.

2. **Application of the AC processors:**

   Participants will apply their AC schemes for a set of test sites keeping the processing parameters constant. The results will be submitted for analysis to ACIX coordinators.

3. **Analysis of the results:**

   ACIX coordinators will process the results submitted by all participants and will assess the inter-comparison outputs based on the agreed metrics. All the results will be presented and discussed during the 2nd ACIX workshop.

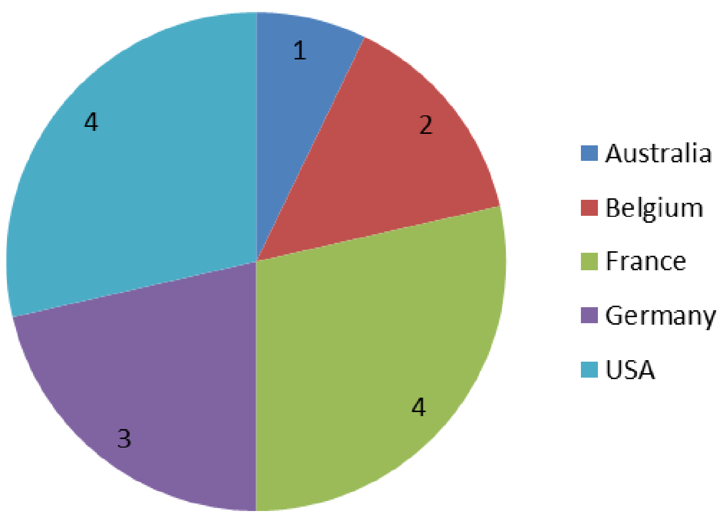

START
ACIX coordinators distribute to the participants the image data acquired over the test sites
ACIX participants access and download the data
ACIX participants run their atmospheric correction processors themselves, keeping the processing parameters constant
ACIX participants submit their results and information about the implementation
ACIX web and FTP interface
ACIX coordinators retrieve the submitted results and reports
ACIX coordinators analyse the results and report the inter-comparison outputs
ACIX coordinators and participants prepare a synthesis of all the experimental results to be published in the scientific literature
Test and Submission Phase
END Of Test and Submission Phase
Results Inter-Comparison & Publishing
END

- When?

Important Dates	
~~1st Workshop Announcement~~	~~25 January 2016~~
~~1st Workshop Registration Deadline~~	~~15 March 2016~~
~~1st Workshop Preliminary programme~~	~~30 April 2016~~
~~Proposals for AC inter-comparison protocol Deadline~~	~~31 May 2016~~
~~1st Workshop of CEOS-WGCV Atmospheric Correction Inter-comparison Exercise~~	~~21-22 June 2016~~
Results Submission Deadline	15 October 2016
Results Analysis Report	15 December 2016
2nd Workshop of CEOS-WGCV Atmospheric Correction Inter-comparison Exercise	1st quarter of 2017

- Who?

- **14** atmospheric correction processors
- **15** organisations, institutes, universities, companies
- **5** countries: Australia, Belgium, France, Germany, USA



Registered Participants

Name		Organization/ Company	AC Processor	Country	Input Data
1	Eric, VERMOTE Jean-Claude, ROGER	NASA, Maryland University	**L8SR**, name of S-2 TBD	USA	Landsat-8 & Sentinel-2
2	Jerome, LOUIS	Telespazio France	**Sen2Cor**	France	Sentinel-2
3	Pflug, BRINGDRIED	DLR - German Aerospace Center	**Sen2Cor, ATCOR**	Germany	Landsat-8 & Sentinel-2
4	André, HOLLSTEIN	Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum GFZ	**SCAPE-M**	Germany	Sentinel-2
5	Oleg, DUBOVIK	LOA, University of Lille -1	**GRASP**	France	
6	Steven, ADLER-GOLDEN	Spectral Sciences, Inc.	**FLAASH**	USA	Landsat-8 & (probably) Sentinel-2
7	Larry, LEIGH	South Dakota State University	**SMACAA**	USA	Landsat-8 & (probably) Sentinel-2
8	Erwin, WOLTERS Sterckx, SINDY	VITO	**OPERA (An Operational Atmospheric Correction for Land and Water)**	Belgium	Landsat-8 & Sentinel-2
9	Quinten, VANHELLMONT Kevin, RUDDICK	Royal Belgian Institute for Natural Sciences	**ACOLITE**	Belgium	Landsat-8 & (most probably) Sentinel-2
10	Antoine, MANGIN	ACRI-HE	**LAC (for Land Atmospheric Correction)**	France	Landsat-8 & Sentinel-2
11	Olivier, HAGOLLE	CNES	**MACCS**	France	Landsat-8 & Sentinel-2
12	Fuqin, LI Lan-Wei, WANG	Geoscience Australia	**GA-PABT**	Australia	
13	David, FRANTZ	Trier University	**lnd-prepro**	Germany	Landsat-8 & Sentinel-2
14	Grit, KIRCHES	Brockmann Consult	TBD	Germany	Landsat-8 & Sentinel-2

DATA Format

Name		Organization / Company	AC Processor	Input Data	Output Format
1	Eric, VERMOTE Jean-Claude, ROGER	NASA / UMd	**L8SR, S2SR**	L8 & S2	**HDF (*.hdf)**
2	Jerome, LOUIS	Telespazio	**Sen2Cor**	S2	**JPEG2000 (*.jp2)**
3	Pflug, BRINGDRIED	DLR	**Sen2Cor, ATCOR**	L8 & S2	**ENVI (*.hdr)**
4	André, HOLLSTEIN	GFZ	**SCAPE-M**	S2	**JPEG2000 (*.jp2)**
5	Oleg, DUBOVIK	LOA,	**GRASP**		**N/A**
6	Steven, ADLER-GOLDEN	Spectral Sciences, Inc.	**FLAASH**	L8 & (probably) S2	**N/A**
7	Larry, LEIGH	SDSU	**SMACAA**	L8 & (probably) S2	**N/A**
8	Erwin, WOLTERS Sterckx, SINDY	VITO	**OPERA**	L8 & S2	**GeoTif (*.tif)**
9	Quinten, VANHELLMONT Kevin, RUDDICK	RBINS	**ACOLITE**	L8 & (probably) S2	**NetCDF, GeoTiff (*.nc, *.tif)**
10	Antoine, MANGIN	ACRI-HE	**LAC**	L8 & S2	**N/A**
11	Olivier, HAGOLLE	CNES	**MACCS**	L8 & S2	**N/A**
12	Fuqin, LI Lan-Wei, WANG	Geoscience Australia	**GA-PABT**		**ENVI (*.hdr)**
13	David, FRANTZ	Trier University	**lnd-prepro**	L8 & S2	**ENVI (*.hdr)**
14	Grit, KIRCHES	Brockmann Consult	TBD	L8 & S2	**GeoTif (*.tif)**

- Where?

1st ACIX workshop (21-22 June 2016) venue:

College Park Marriott Hotel & Conference Center

2nd ACIX workshop venue:

At ESRIN during 1st quarter 2017

- Outcomes of the 1st workshop

- Definition of the **protocol** and **procedures** for inter-comparing products
- Definition of **test regions** and **time periods** for quality assessment
- Description of a **coordinated plan** for inter-comparison activities

What should be included in atmospheric correction ?

>> Mandatory run:

- Rayleigh and aerosol scattering
- gas absorption
- *adjacency effects (if it cannot be turned off)*

>> Optional run:

Including any other correction, e.g.:

- BRDF correction
- adjacency effects
- topography effects
- sun glint effects (over water-surface)
- cirrus/haze correction

Sample results were submitted by 15/7/2016

	TEST SITES	Zone	Land Cover	AERONET station Lat, Lon
Temperate	Frioul [France]	MidlatitudeN	vegetated, bare soil, coastal	43.266, 5.293
	Davos [Switzerland]	Boreal	forest, snow, agriculture	46.813, 9.844
	Beijing [China]	MidlatitudeN	urban, mountains	39.977, 116.381
	Canberra [Australia]	MidlatitudeS	urban, vegetated, water	-35.271, 149.111
	Pretoria_CSIR-DPSS [South Africa]	SubTropicalS	urban, semi-arid	-25.757, 28.280
	Sioux_Falls [USA]	MidlatitudeN	cropland, vegetated	43.736, -96.626
	GSFC [USA]	MidlatitudeN	urban, forest, cropland, water	38.992, -76.840
	Yakutsk [Russia]	Polar	forest, river, snow	61.662, 129.367
Arid	Banizoumbou [Niger]	Tropical	desert, cropland	13.541, 2.665
	Capo_Verde [Capo Verde]	SubTropicalN	desert, ocean	16.733, -22.935
	SEDE_BOKER [Israel]	MidlatitudeN	desert	30.855, 34.782
Equatorial Forest	Alta_Floresta [Brazil]	Tropical	cropland, urban, forest	-9.871, -56.104
	ND_Marbel_Univ [Philippines]	Tropical	cropland, urban, forest	6.496, 124.843
Boreal	Rimrock [USA]	Boreal	semi-arid	46.487, -116.992
Coastal Sites	Thornton C-power (Belgium)	Boreal	water, vegetated	51.532, 2.955
	Gloria [Romania]	MidlatitudeN	water, vegetated	44.600, 29.360
	Sirmione_Museo_GC (Italy)	Boreal	water, vegetated , urban	45.500, 10.606
	Venice (Italy)	Boreal	water, vegetated , urban	45.314, 12.508
	WaveCIS (USA)	SubTropicalN	water,vegetated	28.867, -90.483

Time period for the input data availability

Landsat-8 data:
1/6/2015 – June 2016

Sentinel-2 data:
1/10/2015 – June 2016

AERONET lev 1.5 data (Version 2 Direct Sun Algorithm):
1/6/2015 – June 2016

Aerosol Validation

Water Vapour

Surface Reflectance

- Aerosol Validation

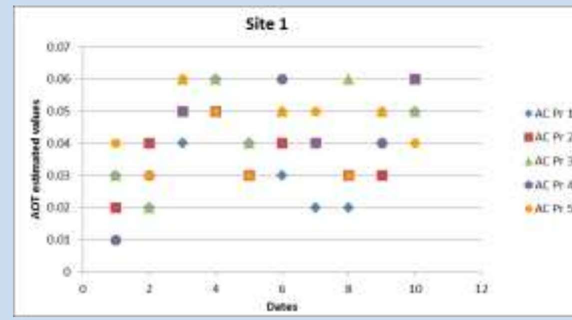
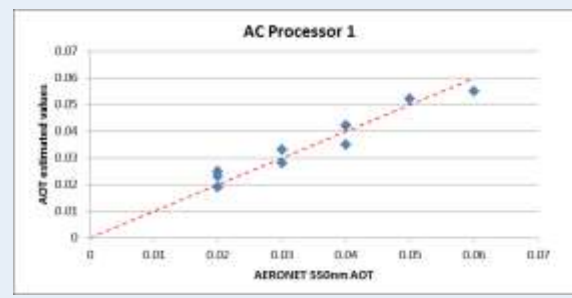
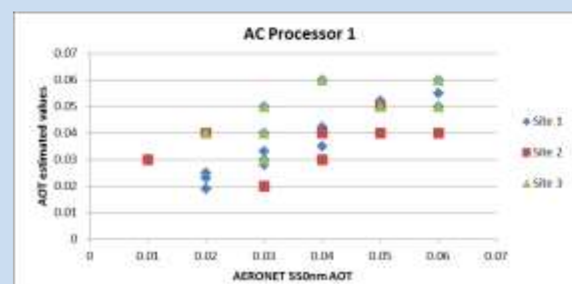
Comparison between resulted AOT & Level 1.5 (cloud screened) AERONET data

1. **Interpolate** AERONET values @ λ=550 nm using the Angstrom Exponent
2. **Average** AERONET values over **time period** of **30min** from AOT retrieved values (image acquisition time)
3. **Average AOT values** over an i**mage subset** of **9 km x 9 km** centred on the AERONET Sunphotometer station

Visualization of Inter-comparison Results

- Scatter plots per date and method
- Time series plots of the submitted AOT values (y axis) against AERONET (x axis)

- Aerosol Validation

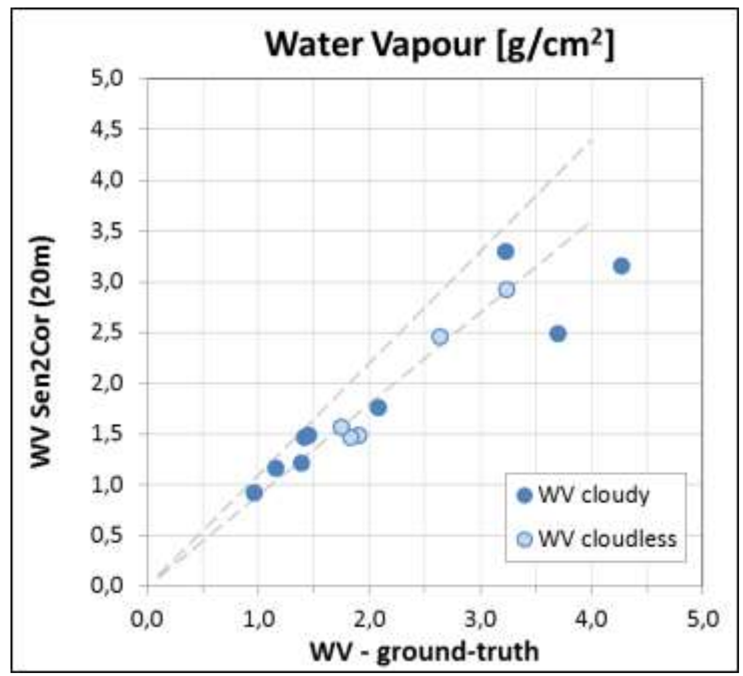
Plot	X axis	Y axis	Plot Example
#1: One plot per test site for all the AC processors (including the AERONET value)	Dates	AOT results	
#2: One plot per AC processor & test site	AERONET measurements	AOT results	
#3: One plot per AC processor for all the test sites	AERONET measurements	AOT results	

- Plots including cloudiness

Comparison by statistical analysis
of difference |retrieval – reference|

- One table per processor
- Table subdivided by cloudiness, zone and test site

.\.		Sen2Cor AOT (20m) - Reference AOT		
	No. of samples	Min	Mean ± rms	Max
Cloudiness	**<65%**			
Boreal	1	0.035	0.035	0.035
subtropical N	7	0.036	0.226 ± 0.140	0.480
Tropical	3	0.016	0.158 ± 0.215	0.405
Midlatitude S	3	0.122	0.222 ± 0.088	0.282
Total	14	0.016	0.197 ± 0.142	0.480
Cloudiness	**<5%**	and	„No DDV“ excluded	
Boreal	1	0.035	0.035	0.035
Tropical	2	0.016	0.034 ± 0.026	0.053
Total	3	0.035	0.035 ± 0.019	0.053



Aerosol Validation
Water Vapour
Surface Reflectance

- Inter-comparison of the BOA products

>> *Visualization of Inter-comparison Results*

- **Histograms** per date, band and AC approach
- **Profile plots** across the images per date, band and AC approach
- **Time series plots** of the estimated Surface Reflectance

>> *NDVI calculation and comparison:* indicator for relative inter-band differences

>> *Quantification of Inter-comparison Results*

- **Distance matrix N x N** *>> N = AC processors, d = normalized distances between the resulting BOA values of a 9 km x 9 km subset averaged over the available dates*

	AC Processor 1	AC Processor 2	AC Processor 3	...	AC Processor n
AC Processor 1	0	d_{12}	d_{13}	...	d_{1n}
AC Processor 2	d_{21}	0	d_{23}	...	d_{21}
AC Processor 3	d_{31}	d_{21}	0	...	d_{3n}
....	...	...	...	...	...
AC Processor n	d_{n1}	d_{n2}	d_{n3}	...	0

- Comparison with AERONET corrected data

>> Atmospherically corrected data will be generated by a **radiative transfer model**, like libRadtran or 6S, using **AERONET data**

>> **Pixel-by-pixel comparison** between each of the spectral bands and the corresponding AERONET corrected surface reflectance data will be done for all the 9 km × 9 km subsets

>> Only the non-saturated, non-cloudy and non-missing pixels will be considered in the comparison (**Quality flags** will be provided by the participants)

- Comparison with AERONET corrected data

$$\Delta\rho_{i,\lambda}^{SR} = \rho_{i,\lambda}^{SR_{PROCESSOR}} - \rho_{i,\lambda}^{SR\ AERONET} \qquad (1)$$

The statistical metrics accuracy, precision and uncertainty (RD1, RD2) will be then estimated:

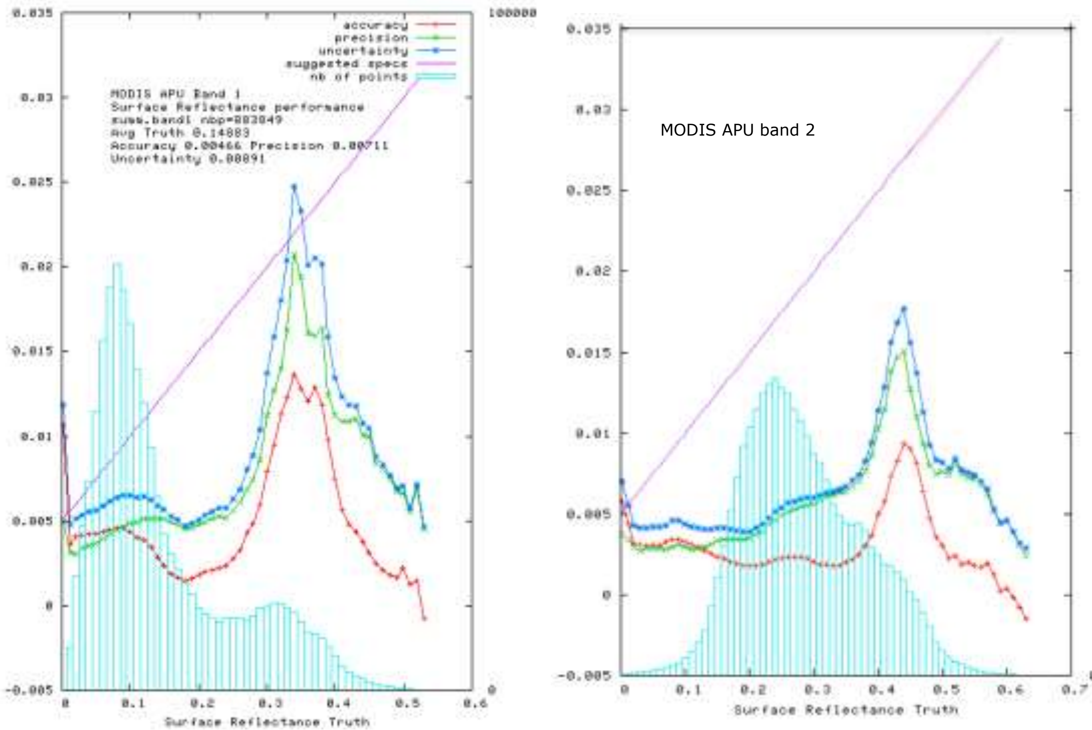
- Accuracy (A): $A = \frac{1}{n_\lambda}\left(\sum_{i=1}^{n_\lambda} \Delta\rho_{i,\lambda}^{SR}\right)$ (2)

- Precision (P): $P = \sqrt{\frac{1}{(n_\lambda - 1)}\left(\sum_{i=1}^{n_\lambda} \Delta\rho_{i,\lambda}^{SR} - A\right)^2}$ (3)

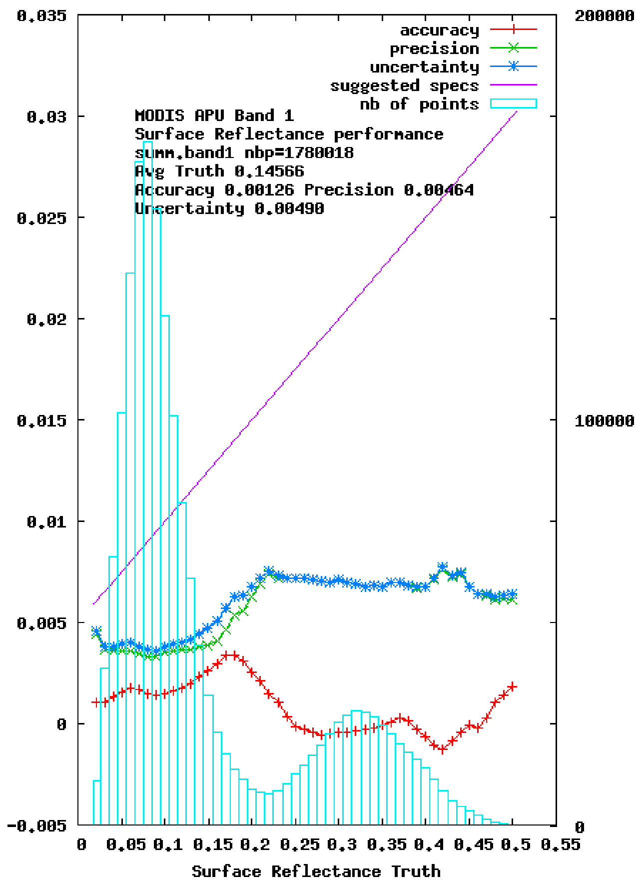
- Uncertainty (U) and relative uncertainty (rU):

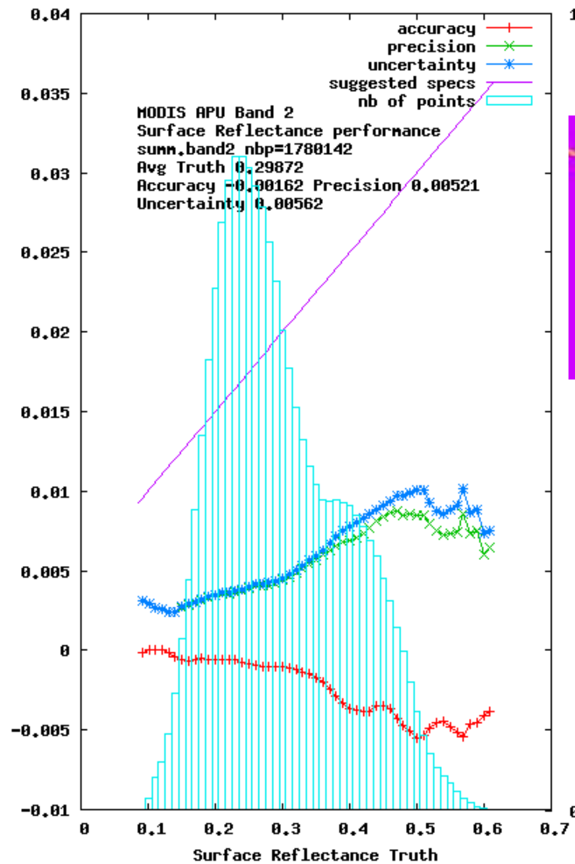
$$U = \sqrt{\frac{1}{n_\lambda}\sum_{i=1}^{n_\lambda}(\Delta\rho_{i,\lambda}^{SR})^2} \qquad (4)$$

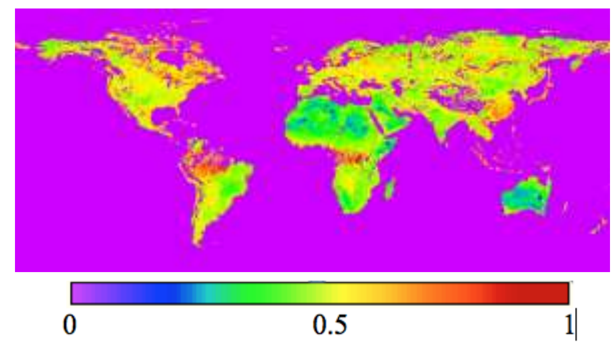
$$rU = \frac{U}{\bar{\rho}_{\lambda,AERONET}^{SR}} \qquad (5)$$



MODIS COLLECTION 5: accuracy or mean bias (red line), Precision or repeatability (green line) and Uncertainty or quadratic sum of Accuracy and Precision (blue line) of the surface reflectance in band 1 in the Red (left), band 2 in the Near Infrared (right) also shown is the uncertainty specification (the line in magenta), that was derived from the theoretical error budget. Data collected from Terra over 200 AERONET sites from 2000 to 2009.







ratio band3/band1 derived using MODIS top of the atmosphere corrected with MISR aerosol optical depth

MODIS COLLECTION 6: accuracy or mean bias (red line), Precision or repeatability (green line) and Uncertainty or quadratic sum of Accuracy and Precision (blue line) of the surface reflectance in band 1 in the Red (left), band 2 in the Near Infrared (right) also shown is the uncertainty specification (the line in magenta), that was derived from the theoretical error budget. Data collected from Terra over 200 AERONET sites for the whole Terra mission.

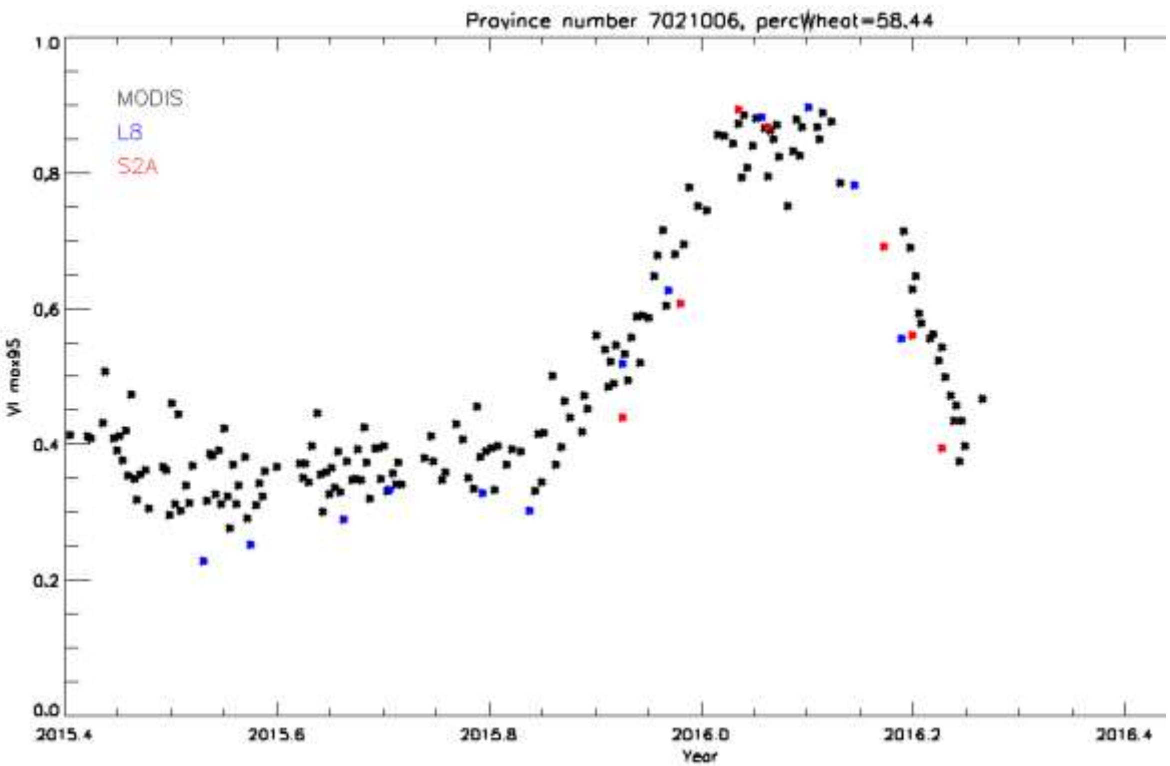
- Comparison with MODIS (MOD09CMG) daily SR products

>> **Pixel-by-pixel comparison** between each of the spectral bands and the corresponding most similar MODIS band. Due to the different satellite orbits, the direct comparison of the SR could deliver misleading results. Therefore, the adjustment of MODIS bidirectional reflectance distribution function to the corresponding Landsat-8 and Sentinel-2 sun and view geometry is required.

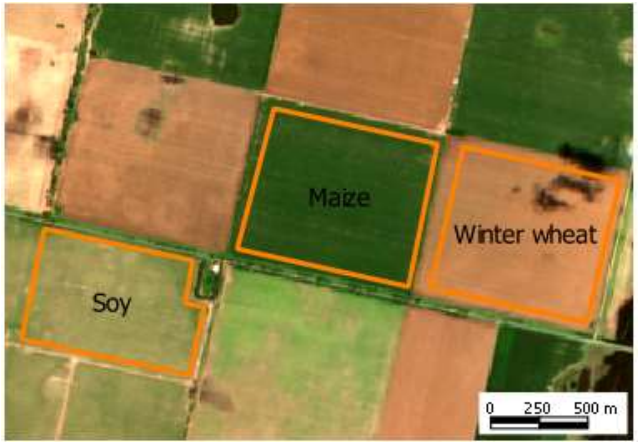
>> Same metrics as before (*residuals, accuracy, uncertainty, etc*.)

CMG MODIS product

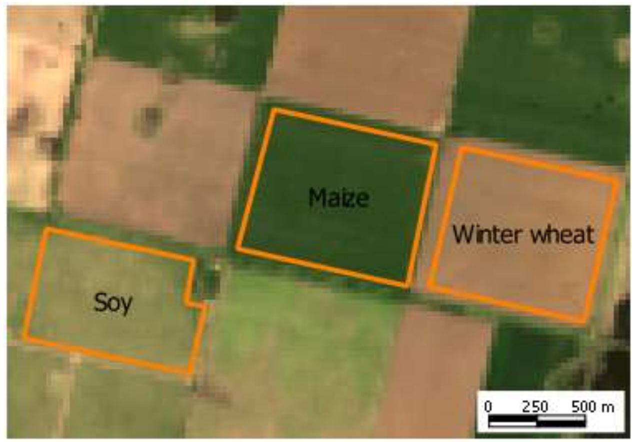
NDVI aggregated at **CMG resolution**.
summer crops (maize-soy)



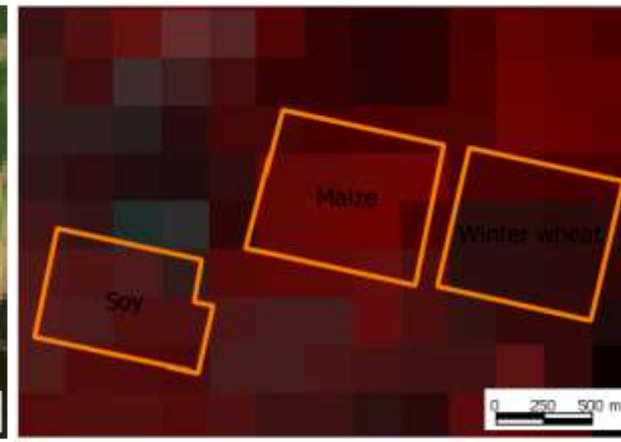
Temporal information is now available at the field level



Sentinel-2A image acquired on 04-Dec-15, 10m, true color B04-03-02 (SR, scaled 0-



Landsat-8 image acquired on 04-Dec-15, 30m, true color B4-3-2 (SR,



MOD09GQ image acquired on 04-Dec-15, 250m, false color B2-1-1, SR

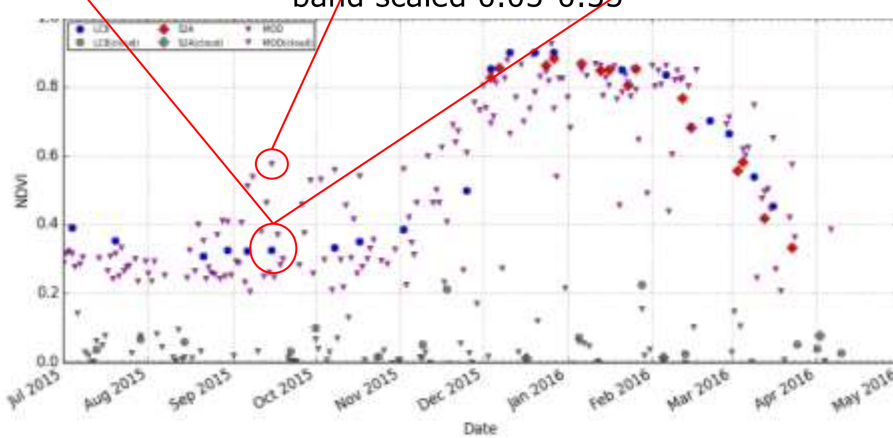
Sentinel-2A image acquired on 23-Jan-16, 10m, true color B04-03-02 (SR, scaled 0-0.15)

Landsat-8 image acquired on 21-Jan-16, 30m, true color B4-3-2 (SR, scaled 0-0.15)

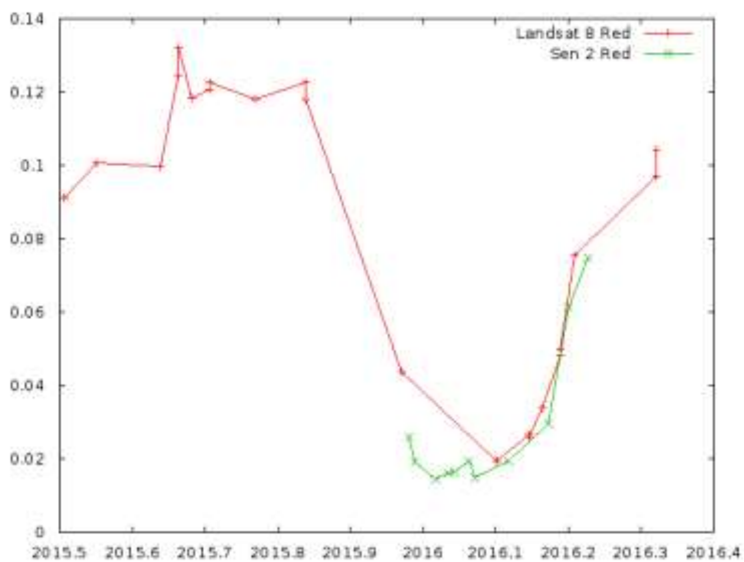
LC8 acquired on **15-Sep-2015** (30m). SR NIR band scaled 0.05-0.55

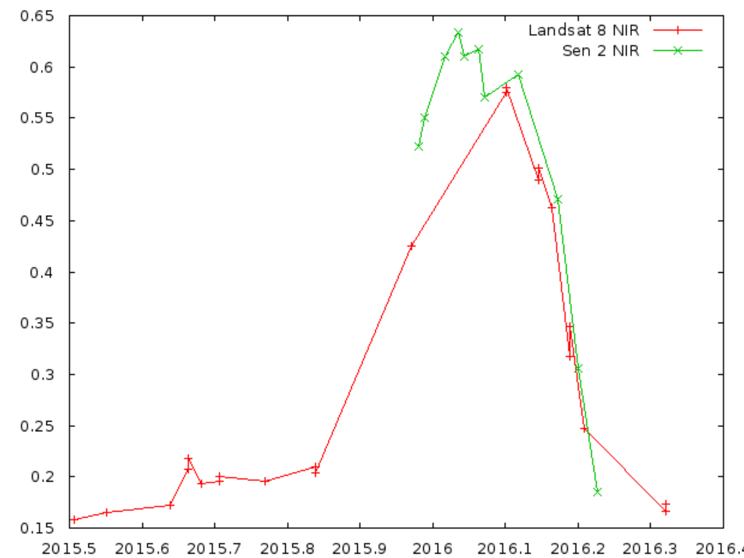
MODIS/Terra (MOD09GQ) acquired on **15-Sep-2015** (250 m). SR NIR band scaled 0.05-0.55

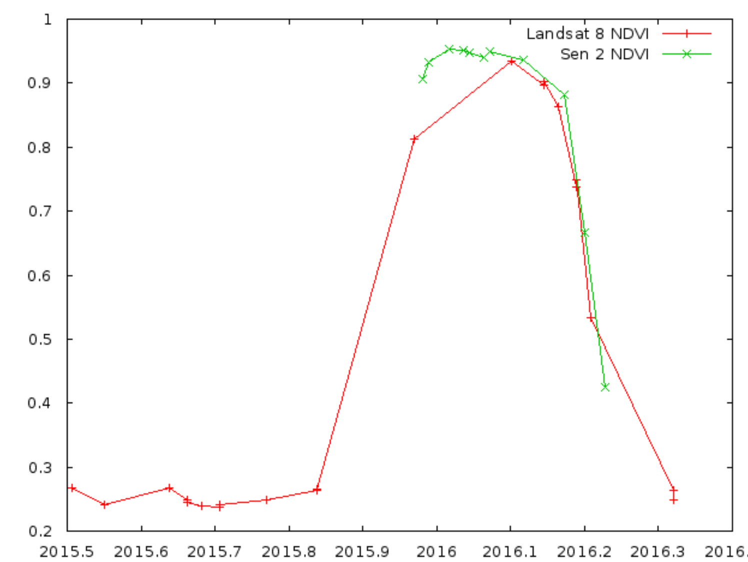
MODIS/Terra (MOD09GQ) acquired on **16-Sep-2015** (250 m). SR NIR band scaled 0.05-0.55



Maize


Landsat 8 Red
Sen 2 Red
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2015.5
2015.6
2015.7
2015.8
2015.9
2016
2016.1
2016.2
2016.3
2016.4


Landsat 8 NIR
Sen 2 NIR
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
2015.5
2015.6
2015.7
2015.8
2015.9
2016
2016.1
2016.2
2016.3
2016.4


Landsat 8 NDVI
Sen 2 NDVI
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
2015.5
2015.6
2015.7
2015.8
2015.9
2016
2016.1
2016.2
2016.3
2016.4

Thank you for your attention!

ACIX website:
https://earth.esa.int/web/sppa/meetings-workshops/acix